Atmospheric Infrared Sounder/Advance Microwave Sounding Unit (AIRS/AMSU)

Specific Humidity Description

1. Intent of This Document

1a) This document is intended for users who wish to compare satellite derived observations with climate model outputs in the context of the CMIP5/IPCC historical experiments. Users are not expected to be experts in satellite derived Earth system observational data. This document summarizes essential information needed for comparing this dataset to climate model outputs. References are provided at the end of this document to additional information for the expert user.

This NASA dataset is provided as part of an experimental activity to increase the usability of NASA satellite observational data for the model and model analysis communities. This is not a standard NASA satellite instrument product. It may have been reprocessed, reformatted, or created solely for comparisons with the CMIP5 model. Community feedback to improve and validate the dataset for modeling usage is appreciated. Email comments to HQ-CLIMATE-OBS@mail.nasa.gov .

Dataset File Name (as it appears on the ESG):

hus_AIRS_L3_RetStd-v5_200209-201105.nc

husStderr_AIRS_L3_RetStd-v5_200209-201105.nc

husNobs_AIRS_L3_RetStd-v5_200209-201105.nc

1b) Technical point of contact for this dataset:

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2. Data Field Description

CF variable name, units:	hus, 1
Spatial resolution:	The vertical resolution is determined by the CMIP5 mandatory levels. The longitude and latitude resolution is 1 degree by 1 degree.
Temporal resolution and extent:	This data product is a regularly gridded, monthly averaged specific humidity measured by AIRS between September 2002 and May 2011.
Coverage:	Global.

Note: The vertical pressure levels (plev) include all the CMIP5 mandatory levels from 1000 hPa to 10 hPa. However, we only provide the data up to 300 hPa and assign a missing value (1.e20) for levels above 300 hPa because AIRS measurements are not as reliable for levels above 300 hPa as other instruments such as Microwave Limb Sounder (MLS), which is specially designed for the accurate measurements of the atmospheric profiles in the upper troposphere and lower stratosphere.

3. Data Origin

The data used to make this product was obtained from the Goddard Earth Science (GES) DISC data access [1].

The AIRS/AMSU instrument suite is carried on the NASA Aqua spacecraft, in a sun-synchronous orbit at 1:30 local time. The southward/northward moving observations are obtained during daytime/nighttime. (See Section 6 below for an Overview of the AIRS/AMSU instrument suite.) The AIRS/AMSU specific humidity is derived from infrared and microwave radiances measured from space, so is not an *in situ* measurement. The infrared emission radiations emitted by different Earth scenes are remotely sensed by a spectrometer, and the microwave observations are obtained by a radiometer [2]. A single AMSU channel provides a constraint on total precipitable water vapor. First, measurements are transformed into calibrated radiances for all footprints and all channels [3]. Then, physical quantities such as the specific humidity are derived ('retrieved') from these geolocated radiance products [4]. The retrieved physical quantities are then averaged over a month [5]. The data we obtained from the GES DISC [1] was at this last processing level. We then applied an additional processing step to adapt the data according to the CMIP5 model output format.

This data product is the monthly average of the AIRS/AMSU retrieved specific humidity profiles in the regularly gridded 1 degree by 1 degree latitude and longitude boxes. In the AIRS/AMSU original data [1], the specific humidity is reported in terms of layer averages. In order to convert from layer amounts to level amounts, we treat the original layer averages as level amounts at the midpoint in log(pressure) of the layers and then logarithmically interpolate in log(pressure) to the desired levels. For the 1000 hPa level this interpolation is replaced by an extrapolation. The extrapolation is done logarithmically in log(pressure) just like the interpolation. It has to be an extrapolation because there is no layer with a higher midpoint pressure than 1000 hPa.

The values described here are means of the daytime and nighttime values, provided there are enough observations in each category to make the values statistically significant. The minimum is 20 observations each, except for latitudes beyond +/- 80 degrees, where we relax the limits to compensate for a much lower number of observations. Since clouds have a significant effect on observed infrared radiances (see section 5.1 below), the retrieval process includes steps to retrieve the specific humidity from radiance in the presence of clouds. The horizontal resolution of each AIRS/AMSU scene is 45 km, and the instrument samples in a swath are 30 scenes wide (see Figure 3 below), yielding 324,000 scenes per day. However, the specific humidity can be inferred in about 70% of these scenes, with the remainder affected by thick clouds or precipitation.

4. Validation

AIRS retrievals have been validated against a variety of in situ data (radiosondes, airborne sun photometer, ship based measurements), other remote measurements from other satellites and model-generated data (fully coupled global ocean- atmosphere General Circulation Models, collocated model forecasts compared with radiosondes). The table below summarizes these findings and can be found in reference [6].

Geophysical Conditions Studied	Uncertainty Estimate
Non-polar ocean, surface to 300 hPa	15-25%
Non-polar land 2 km to 300 hPa.	15-25%
Non-polar land, surface to 1-2 km	30-40%
Polar	30-40%
Tropical upper troposphere.	25%
Middle and high latitude upper troposphere.	30-50%

Table 1: uncertainty estimate for different conditions.

The uncertainty estimates are calculated based on the difference between AIRS retrievals and radiosonde observations. They are given for 2 km layers.

5. Consideration for Model-Observation Comparisons

Because this data product is observational data, there are several aspects that distinguish this product from model outputs. The user of this data product should be aware of them in order to make judicious model-observation comparisons.

5.1 Clouds influence

AIRS/AMSU coverage is limited by the presence of optically thick clouds because AIRS is an infrared instrument. The combination of infrared and microwave radiances allows retrieval of high-resolution humidity profiles for infrared cloud fraction (the product of emissivity and coverage) up to about 70% [7]. This limitation of the infrared measurement makes the AIRS/AMSU observation scene dependent and in turn, causes a spatially inhomogeneous sampling as illustrated on Figure 1. The AIRS sampling is low (~60) in cloudy regions, such as the Intertropical Convergence Zone (ITCZ) (e.g., the equatorial western Pacific warm pool) and the midlatitude storm tracks (e.g., north Pacific, north Atlantic and 60°S latitude belt). The AIRS sampling is high (~150) in clear regions, such as subtropics and midltitude land regions. See reference [8] for more on the implication of cloud-induced sampling in AIRS/AMSU observations.

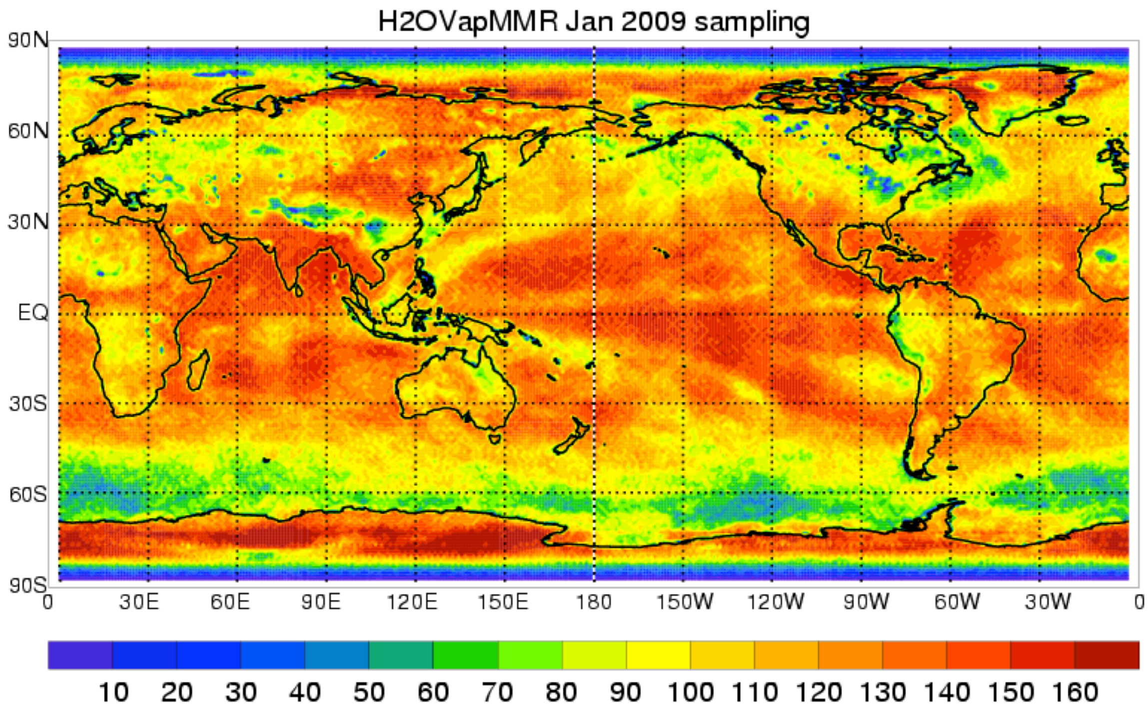

Figure 1: Water vapor sampling at 550 hPa for the month of January 2009.

5.2 Asynoptic Time Sampling

Because Aqua satellite is in a sun-synchronous polar orbit, AIRS samples the atmosphere at two fixed local solar times at each location (e.g. 1:30 AM and 1:30 PM at the equator) and cannot fully resolve the diurnal cycle. In contrast, typical model monthly averaged outputs contain the averaged values over a time series of data within a fixed time interval (e.g. every 6 hours). For specific humidity over ocean and in the upper atmosphere with a small diurnal cycle, this difference is not likely a problem. However, for specific humidity in the boundary layer or over land regions strongly influenced by the diurnal cycle, this time sampling limitation should be considered.

5.3 Inhomogeneous Sampling

Because the monthly averaged value in this AIRS data product is an average over observational data available in a given grid cell (see Figure 1), the number of samples used for averaging varies with the geo-location of the cell. Because of the convergence of longitude lines near the poles, the time range of data collection broadens as one moves from the equator toward either pole, with the ranges in the polar regions including all times of day and night [9]. So, there are more observations in the regions near the poles (~70° to ~85°) than the rest of the area.

5.5 Missing data

AIRS went into a safe mode at the end of October 2003 to avoid possible damage from a large solar flare. It did not resume data flow until mid November 2003. Our preparation of this product for CMIP5 added a requirement of a minimum number of observations for each grid square from each of ascending and descending orbits. With only half of a month data, many grids cells do not meet these criteria for November 2003. The only significant outage since December 2003 was the safe mode event from January 9th to the 26th, 2010. So the January 2010 product has about half the data of a full month. However, there should be no bias introduced in comparing the data from January 2010 to January of other years.

Furthermore, we excluded the AIRS data within 100 hPa above the land surface. As a result, most AIRS data are missing over land for 1000 hPa and 925 hPa levels.

6. Instrument Overview

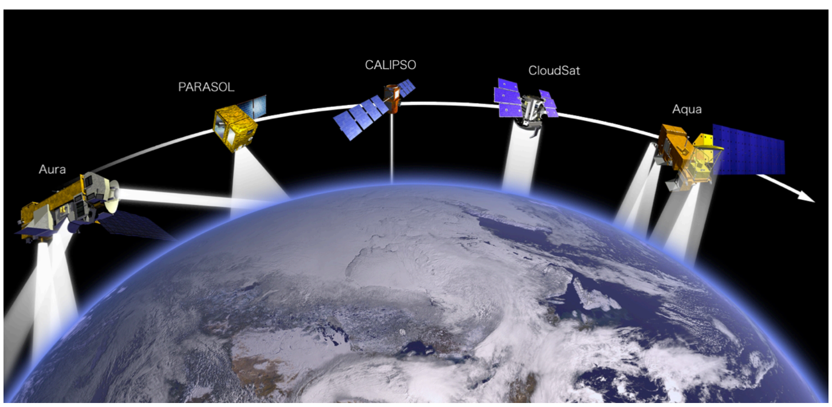

Figure 2: NASA's A-train group of Earth observing satellites.

Launched into Earth-orbit on May 4, 2002, Aqua is part of NASA's "A-train" satellite constellation (see Figure 2), a series of high-inclination, Sun-synchronous satellites in low Earth orbit designed to make long-term global observations of the land surface, biosphere, solid Earth, atmosphere, and oceans. The Atmospheric Infrared Sounder (AIRS) and its partner microwave instrument, Advanced Microwave Sounding Unit (AMSU), share the Aqua satellite with the Moderate Resolution Imaging Spectroradiometer (MODIS), Clouds and the Earth's Radiant Energy System (CERES), and the Advanced Microwave Scanning Radiometer-EOS (AMSR-E). AIRS/AMSU observe the global water and energy cycles, climate variation and trends, and the response of the climate system to increased greenhouse gases. The term "sounder" in the instrument's name refers to the fact that temperature and water vapor are measured as functions of height.

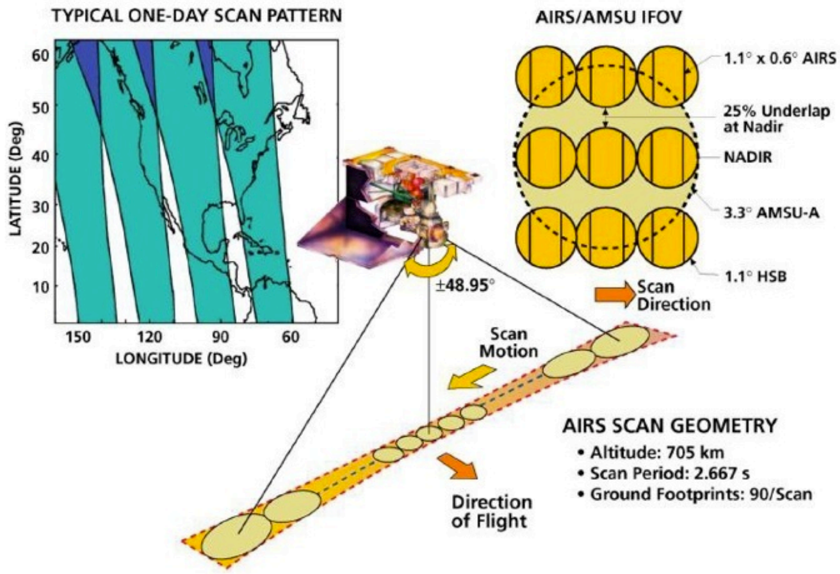

Figure 3: AIRS scanning and coverage geometry.

AIRS coverage is pole-to-pole and covers the globe two times a day. Because the swaths (scanning sweeps) do not overlap at low latitudes, some points near the equator are missed. However, these points are eventually scanned within 2-3 days. As depicted on Figure 3, AIRS scans laterally with respect to its direction of flight. With the scanning angle being 49.5 degree about nadir, the swath width is 1650 km. One orbit period is 98.8 minutes [10].

7. References

[1] http://disc.sci.gsfc.nasa.gov/AIRS/data-holdings

[2] Hartmut H. Aumann *et al.* (2003), "AIRS/AMSU/HSB on the Aqua Mission: Design, Science Objectives, Data Products, and Processing Systems", IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 41, NO. 2.

[3] Level-1B AIRS IR

[4] Level-2 Standard Products Quick Start

[5] Level-3 Standard 1x1° Gridded Products Quick Start

[6] V5_CalVal_Status_Summary.pdf, page 8. Note: there are some errors in the document V5_CalVal_Status_Summary.pdf, page 8. We corrected these errors in the present document.

[7] Joel Susskind *et al.* (2003), "Retrieval of Atmospheric and Surface Parameters From AIRS/AMSU/HSB Data in the Presence of Clouds", IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 41, NO. 2, page 390.

[8] Fetzer, E. J., *et al.*, (2006), Biases in total precipitable water vapor climatologies from Atmospheric Infrared Sounder and Advanced Microwave Scanning Radiometer, *J. Geophys. Res., 111*, D09S16, doi:10.1029/2005JD006598.

[9] Claire L. Parkinson (2003), "Aqua: An Earth-Observing Satellite Mission to Examine Water and Other Climate Variables", IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 41, NO. 2.

[10] http://airs.jpl.nasa.gov/instrument/coverage/

8. Revision History

Rev 0 – Tuesday, September 6, 2011